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This invention relates to a lubricating oil for
10 compressors of refrigerators using therein a hydrogen-
containing halogenocarbon as a refrigerant (the oil being
hereinafter referred to as "a refrigerator oil for use with
a hydrogen-containing halogenocarbon refrigerant") and, more
specifically, it relates to such a refrigerator oil which
15 comprises a specific ester as a base oil and is superior in
various properties.

Generally, naphthenic mineral oils, paraffinic mineral oils, alkylbenzenes, polyglycolic oils, ester oils and mixtures thereof, which have each a kinematic viscosity of 10 - 200 cSt at 40°C, as well as these oils incorporated with suitable additives have been used as refrigerator oils.

Of these CFCS, CFCS such as CFC-11, CFC-12 and CFC-113, which are obtained by substituting all the hydrogen

atoms of hydrocarbons thereof by halogen atoms including chlorine atoms, may lead to the destruction of the ozone layer, and therefore, the use of the CFCS has been controlled. Accordingly, hydrogen-containing

5 halogenocarbons, such as HFC-134a and HFC-152a, have been being used as substitutes for CFCs. HFC-134a is especially promising as a substitute refrigerant since it is similar in thermodynamic properties to CFC-12 which has heretofore been used in many kinds of refrigerators of home cold-storage
10 chests, air-conditioners and the like.

Refrigerator oils require various properties, among which their compatibility with refrigerants is extremely important in regard to lubricity and system efficiency in refrigerators. However, conventional refrigerator oils
15 comprising, as the base oils, naphthenic oils, paraffinic oils, alkylbenzenes, heretofore known ester oils and the like, are hardly compatible with hydrogen-containing halogenocarbons such as HFC-134a. Therefore, if ~~said~~ ^{these}
conventional refrigerator oils are used in combination with
20 HFC-134a, the resulting mixture will separate into two layers at normal temperature so as to degrade the oil-returnability which is the most important within the refrigeration system and cause various troubles such as a decrease in refrigeration efficiency, ~~the~~ deterioration of
25 lubricity and the consequent seizure of the compressor within the system whereby the refrigerator oils are made unsuitable for use as such. In addition, polyglycolic oils

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[illegible]

20 On the other hand, refrigerator oils used in
compressors of home refrigerators and the like are required
to have a high electrical insulating property. Among the
known refrigerator oils, alkylbenzenes and the mineral oils
have the highest insulating property, but they are hardly
25 compatible with hydrogen-containing halogenocarbons such as
HFC-134a as mentioned above. WO 90/12849 describes a
composition comprising a hydrogen-containing halogenocarbon

and a specific ester lubricant. No refrigerator oil having both high compatibility with hydrogen-containing halogenocarbons such as HFC-134a and a high insulating property has been developed prior to the present invention.

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Summary of the Invention

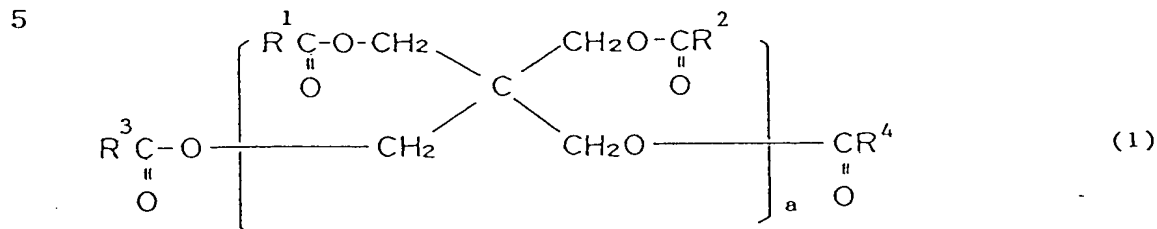
10 The present inventors made various intensive studies in attempts to develop refrigerator oils which can meet the aforesaid requirements and, as the result of their studies, they found that esters having specific structures have excellent compatibility with hydrogen-containing halogenocarbons such as HFC-134a, and a high electrical insulating property as well as excellent lubricity. This
15 invention is based on this finding.

The object of this invention is to provide refrigerator oils for use with hydrogen-containing halogenocarbons refrigerants, the oils comprising as a major component (or a base oil) at least one kind of ester having
20 a specific structure and an epoxy compound and having excellent compatibility with hydrogen-containing halogenocarbons such as HFC-134a, high electrical insulating property, high wear resistance, low hygroscopicity, and high thermal and chemical stability.

25 The present invention provides a refrigerator oil for use in compressors using therein a hydrogen-containing halogenocarbon as a refrigerant, consisting essentially of

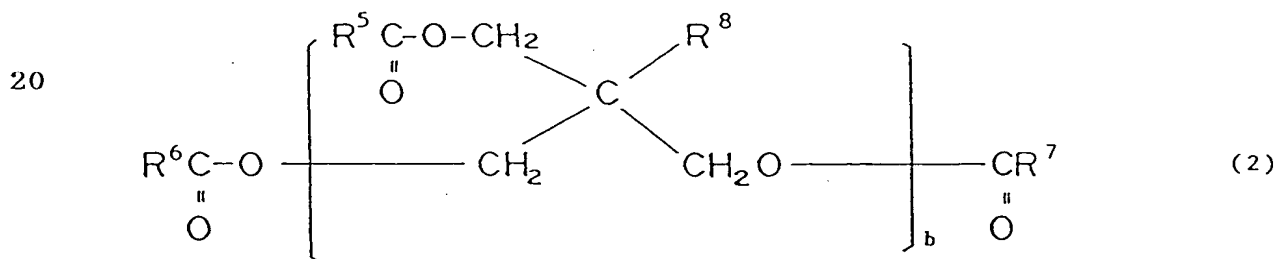
as a base oil at least one ester selected from the group consisting of:

[I] a pentaerythritol ester represented by the general formula (1)



10 wherein R¹-R⁴ may be identical with or different from each other and are each selected from the group consisting of straight-chain alkyl groups having 3 to 11 carbon atoms, branched-chain alkyl groups having 3 to 15 carbon atoms and
 15 cycloalkyl groups having 6 to 12 carbon atoms and a is an integer of 1 to 3;

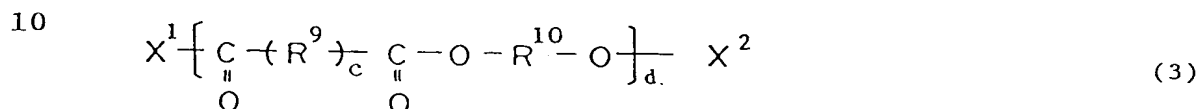
[II] a polyol ester represented by the general formula (2)



25 wherein R⁵-R⁷ may be identical with or different from each other and are each selected from the group consisting of straight-chain alkyl groups having 3 to 11 carbon atoms,

branched-chain alkyl groups having 3 to 15 carbon atoms and cycloalkyl groups having 6 to 12 carbon atoms, the straight-chain alkyl groups being present in a ratio of not more than 60 % of the total alkyl groups, R⁸ is selected from the group consisting of methyl, ethyl and propyl groups, and b is an integer of 1 to 3;

[III] an ester represented by the general formula (3)



wherein X¹ is a group represented by the general formula -OR¹¹ or -O-R¹²-O-C- $\underset{\text{O}}{\underset{\parallel}{\text{C}}}$ -R¹³, X² is a group represented

by the general formula $\underset{\text{O}}{\underset{\parallel}{\text{C}}}$ -R¹⁴ or $\underset{\text{O}}{\underset{\parallel}{\text{C}}} - (\text{R}^{15})_e - \underset{\text{O}}{\underset{\parallel}{\text{C}}} - \text{OR}^{16}$, R⁹ and

R¹⁵ are each a divalent hydrocarbon group having 1 to 8 carbon atoms, R¹⁰ and R¹² are each a divalent saturated hydrocarbon group having 2 to 16 carbon atoms, R¹¹ and R¹⁶ are each a branched-chain alkyl group having 3 to 15 carbon atoms, R¹³ and R¹⁴ are each a branched-chain alkyl group having 3 to 14 carbon atoms, c and e are each an integer of 0 or 1 and d is an integer of 0 to 30; and

[IV] a polyol ester obtained by the synthesis of, as raw materials, (a) a neopentyl type polyhydric alcohol having 5 to 6 carbon atoms and 3 to 4 hydroxyl groups, (b) a straight-chain monocarboxylic acid and/or a branched-chain
5 monocarboxylic acid, the branched-chain monocarboxylic acid being present in a ratio of not less than 50 mol% of the total monocarboxylic acids, (c) a dicarboxylic acid: and further comprising at least one epoxy compound.

First, the pentaerythritol esters [I] will be
10 explained in detail. In the formula (1), R^1-R^4 may be identical with, or different from, each other and are each a
substituent
~~group~~ selected from the group consisting of straight-chain
1 alkyl groups having 3-11 carbon atoms, preferably 3-7 carbon atoms, branched-chain alkyl groups having 3-15 carbon atoms,
15 preferably 4-11 carbon atoms and cycloalkyl groups having 6-12 carbon atoms, preferably 6-8 carbon atoms. The cycloalkyl groups in this invention may include alkylcycloalkyl groups. In addition, the ratio of the straight-chain alkyl groups to the total alkyl groups is
20 preferably not more than 60%, more preferably not more than 50%. Further, a is an integer of 1-3. Thus, the formula(1) illustrates monopentaerythritol esters, dipentaerythritol esters and tripentaerythritol esters.

R^1-R^4 are each exemplified by n-propyl group, n-butyl
25 group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group,

iso-propyl group, iso-butyl group, iso-pentyl group, iso-hexyl group, iso-heptyl group, iso-octyl group, iso-nonyl group, iso-decyl group, iso-undecyl group, iso-dodecyl group, iso-tridecyl group, iso-tetradecyl group, iso-pentadecyl group, cyclohexyl group, cycloheptyl group, cyclooctyl group, cyclononyl group, cyclodecyl group, cycloundecyl group, cyclododecyl group, methylcyclohexyl group, ethylcyclohexyl group, propylcyclohexyl group, butylcyclohexyl group, pentylcyclohexyl group or
10 hexylcyclohexyl group.

The pentaerythritol esters [I] are esters of pentaerythritol, dipentaerythritol or tripentaerythritol and a monocarboxylic acid, and are ordinarily obtained by the reaction of pentaerythritol, dipentaerythritol,
15 tripentaerythritol or a mixture thereof with a mixture of at least one carboxylic acid having the aforementioned alkyl group.

Secondly, the polyol esters [II] will be explained in detail. In the formula (2), R^5-R^7 may be identical with, or
20 different from, each other and are each a ^{substituent} ~~group~~ selected from the group consisting of straight-chain alkyl groups having 3-11 carbon atoms, preferably 3-7 carbon atoms, branched-chain alkyl groups having 3-15 carbon atoms, preferably 4-11 carbon atoms and cycloalkyl groups having 6-
25 12 carbon atoms, preferably 6-8 carbon atoms. The cycloalkyl groups in this invention may include alkylcycloalkyl groups. With respect to the above R^5-R^7 ,

the ratio of the straight-chain alkyl groups to the total alkyl groups (including cycloalkyl groups) is not more than 60%, preferably not more than 50%. In addition, R^8 is a group selected from the group consisting of methyl group, ethyl group and propyl group. Further, b is an integer of 1-3. Thus, the formula (2) illustrates trimethylolethane esters, trimethylolpropane esters, trimethylolbutane esters and dimers-trimers thereof.

R^5 - R^7 are each exemplified by n-propyl group, n-butyl group, n-pentyl group, n-hexyl group, n-heptyl group, n-octyl group, n-nonyl group, n-decyl group, n-undecyl group, iso-propyl group, iso-butyl group, iso-pentyl group, iso-hexyl group, iso-heptyl group, iso-octyl group, iso-nonyl group, iso-decyl group, iso-undecyl group, iso-dodecyl group, iso-tridecyl group, iso-tetradecyl group, iso-pentadecyl group, cyclohexyl group, cycloheptyl group, cyclooctyl group, cyclononyl group, cyclodecyl group, cycloundecyl group, cyclododecyl group, methylcyclohexyl group, ethylcyclohexyl group, propylcyclohexyl group, butylcyclohexyl group, pentylcyclohexyl group or hexylcyclohexyl group.

The polyol esters [II] are esters of trimethylolethane, trimethylolpropane, trimethylolbutane or a dimer or trimer thereof and a monocarboxylic acid, and are ordinarily obtained by the reaction of trimethylolethane, trimethylolpropane, trimethylolbutane, a dimer or trimer

thereof or a mixture thereof with a mixture of at least one carboxylic acid having the aforementioned alkyl group.

Thirdly, the esters [III] will be explained in detail. In the formula (3), X^1 is a group represented by the general formula $-OR^{11}$ or X^2 is a group represented by the general formula A_1 or A_2 . In addition, R^9 and R^{15} are each a divalent hydrocarbon group having 1-8 carbon atoms, preferably 1-6 carbon atoms, R^{10} and R^{12} are each a divalent saturated hydrocarbon group having 2-16 carbon atoms, preferably 2-9 carbon atoms, R^{11} and R^{16} are each an alkyl group having 1-15 carbon atoms, preferably 1-12 carbon atoms, and R^{13} and R^{14} are each an alkyl group having 1-14 carbon atoms, preferably 1-11 carbon atoms. Further, c and e are each an integer of 0 or 1 and d is an integer of 0-30, preferably 1-30.

R^9 and R^{15} are each exemplified by a methylene group, ethylene group, propylene group, trimethylene group, butylene group, tetramethylene group, pentamethylene group, hexamethylene group, heptamethylene group, octamethylene group, phenylene group, other unsaturated hydrocarbon groups or the like. R^{10} and R^{12} are each illustrated by nonamethylene group, decamethylene group, undecamethylene group, dodecamethylene group, tridecamethylene group, tetradecamethylene group, pentadecamethylene group, hexadecamethylene group, cyclohexylene group or the like in addition to the above alkylene groups (except for methylene

group). R^{13} and R^{14} are each concretely exemplified by straight- or branched-chain alkyl groups, such as methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, octyl group, nonyl group, decyl group, undecyl group, dodecyl group, tridecyl group or tetradecyl group. R^{11} and R^{16} are each illustrated by a straight- or branched-chain alkyl group, such as a pentadecyl group, in addition to any one of the above alkyl groups.

10 The method for producing the esters [III] is not particularly limited. For example, a mixture of the esters [III] can be produced by the esterification reaction of (i) a diol having none of ether linkages in the branched-chains thereof with (ii) a dicarboxylic acid and (iii) a
15 monocarboxylic acid and/or (iv) a monohydric alcohol. The esters [III] are also produced by the reaction of the diol (i) with the monocarboxylic acid (iii) or the reaction of the dicarboxylic acid (ii) with the monohydric alcohol (iii).

20 The diols (i) used herein are those having 2-16 carbon atoms and are exemplified by alkylene glycols such as ethylene glycol, propylene glycol, butylene glycol, trimethylene glycol, tetramethylene glycol, pentamethylene glycol, hexamethylene glycol, heptamethylene glycol,
25 octamethylene glycol, nonamethylene glycol, decamethylene glycol, neopentyl glycol, 2-ethyl-2-methyl-1,3-propanediol,

2-methyl-2-propyl-1,3-propanediol, 2,2-dimethyl-1,3-propanediol, 2-butyl-2-ethyl-1,3-propanediol, 3-methyl-1,5-pentanediol, 2,4-pentanediol, 2-methyl-2,4-pentanediol, 2-methyl-1,6-hexane, 1,4-cyclohexane dimethanol and 2,2-bis
5 (4-hydroxycyclohexyl) propane.

The dicarboxylic acids (ii) used herein are those having 2-10 carbon atoms and are exemplified by saturated aliphatic dicarboxylic acids such as oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic
10 acid, suberic acid, azelaic acid, sebacic acid, methylmalonic acid, ethylmalonic acid, dimethylmalonic acid, methylsuccinic acid, 2,2-dimethylsuccinic acid, 2,3-dimethylsuccinic acid, 2-ethyl-2-methylsuccinic acid, 2-methylglutaric acid, 3-methylglutaric acid, 3,3-
15 dimethylglutaric acid and 3-methyladipic acid; unsaturated aliphatic dicarboxylic acids such as maleic acid, fumaric acid, itaconic acid, citraconic acid and mesaconic acid; and aromatic dicarboxylic acids such as phthalic acid, isophthalic acid and terephthalic acid.

20 The monocarboxylic acids (iii) used herein are those having 2-15 carbon atoms and are exemplified by acetic acid, propionic acid, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, undecanoic acid, dodecanoic acid, tridecanoic acid,
25 tetradecanoic acid, pentadecanoic acid, 3-methylbutanoic

acid, 2-methylbutanoic acid, 2-ethylhexanoic acid, 2,4-dimethylpentanoic acid, 3,3,5-trimethylhexanoic acid and benzoic acid.

The monohydric alcohols (iv) used herein are those
5 having 1-15 carbon atoms and are exemplified by methanol, ethanol, propanol, butanol, pentanol, hexanol, heptanol, octanol, nonanol, decanol, undecanol, dodecanol, tridecanol, tetradecanol, pentadecanol, isopropanol, isobutanol, 2-methyl-1-butanol, 2,2-dimethyl-1-propanol,
10 3,3-dimethyl-1-butanol, 2-methyl-1-pentanol, 3-methyl-1-pentanol, 2,4,4-trimethyl-1-pentanol, 2,2,4-trimethyl-1-pentanol, 2-ethyl-4-methyl-1-pentanol and 2-ethyl-1-hexanol.

The molecular weight of the ester [III] is not particularly limited, but the number average molecular
15 weight of the ester [III] is in the range of preferably 200-3000, more preferably 300-2000, to improve the compressor in sealability

Fourthly, the polyol ester [IV] will be explained in detail.

20 The neopentyl type polyhydric alcohols (a) having 5-6 carbon atoms and 3-4 hydroxyl groups are illustrated by trimethylolethane, trimethylolpropane and pentaerythritol.

The monocarboxylic acids (b) preferably used herein are those having 2-15 carbon atoms and are exemplified by
25 acetic acid, propionic acid, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid,

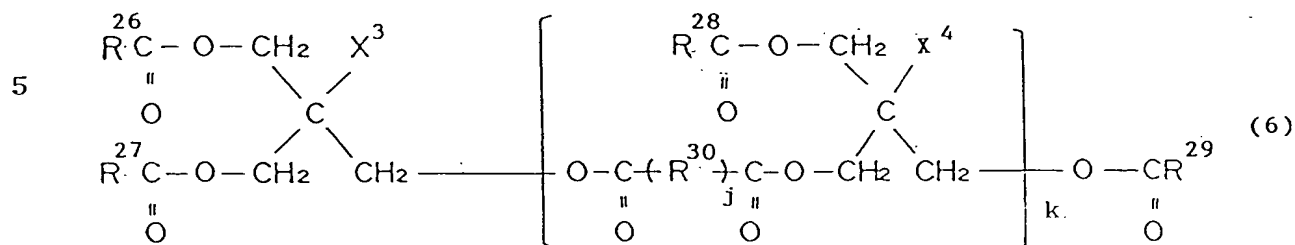
decanoic acid, undecanoic acid, dodecanoic acid, tridecanoic acid, tetradecanoic acid and pentadecanoic acid.

These carboxylic acids may be either straight-chain or branched-chain ones, but it is preferable to use the latter having a branched-chain structure in an amount of not less than 50 mol%, preferably not less than 60 mol%.

The dicarboxylic acids (c) used herein are those having 2-10 carbon atoms and are exemplified by saturated aliphatic dicarboxylic acids such as oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, methylmalonic acid, ethylmalonic acid, dimethylmalonic acid, methylsuccinic acid, 2,2-dimethylsuccinic acid, 2,3-dimethylsuccinic acid, 2-ethyl-2-methylsuccinic acid, 2-methylglutaric acid, 3-methylglutaric acid and 3-methyladipic acid; unsaturated aliphatic dicarboxylic acids such as maleic acid, fumaric acid, itaconic acid, citraconic acid and mesaconic acid; and aromatic dicarboxylic acids such as phthalic acid, terephthalic acid and isophthalic acid.

The esters [IV] are produced by the esterification reaction of the aforesaid component (a) with the component (b) and the component (c) under ordinary esterification conditions, for example, in the presence of an acid catalyst such as sulfuric acid and at an temperature of 100-180°C.

The chemical structure of the ester [IV] according to the present invention is illustrated by the following general formula (6)



wherein X^3 and X^4 may be identical with, or different from, each other and are each an alkyl group having 1-4 carbon atoms or a group represented by the general formula $-\text{CH}_2 - \text{O} - \text{C}(\text{O})\text{R}^{31}$; $\text{R}^{26} - \text{R}^{29}$ and R^{31} may be identical with, or different from each other and are each an alkyl group having 4-15 carbon atoms; R^{30} is an alkylene group having 1-8 carbon atoms; j is an integer of 0 or 1; and k is an integer of 1-5.

The molecular weight of the polyol ester [IV] is not particularly limited, but the number average molecular weight of the ester [IV] is in the range of preferably 200-3000, more preferably 300-2000, to improve the compressor in sealability.

The products obtained by the methods as mentioned above may be refined to remove the by-products and/or unreacted reactants, but the by-products and/or unreacted reactants may be present in small amounts in the

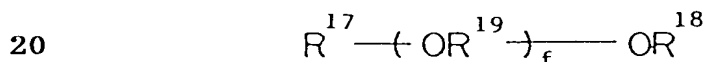
refrigerator oils of the present invention as far as they do not impair the excellent performances thereof.

In the preparation of the refrigerator oils of the present invention, the esters [I]-[IV] mentioned above may
5 be used singly, or jointly as a mixture of at least two kinds of the esters.

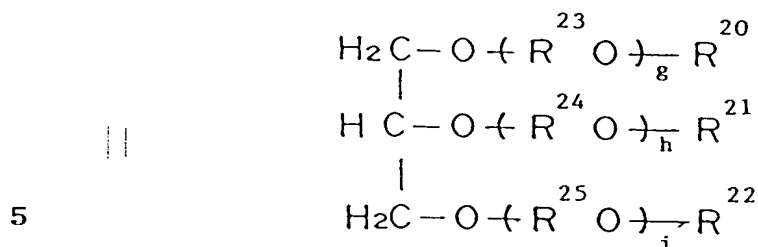
The kinematic viscosities of the esters according to the present invention are in the range of preferably 2-150 cSt, more preferably 5-100 cSt at 100°C.

10 The refrigerator oil of the present invention may comprise as the only base oil at least one member selected from the above esters [I]-[IV] and, as required, it may additionally comprise other base oils for refrigerator oils. Among the other base oils, preferable ones are illustrated
15 as follows:

a polyoxyalkylene glycol or an ether thereof represented by the general formula (4)



wherein R^{17} and R^{18} are each a hydrogen atom or an alkyl group having 1-18 carbon atoms, R^{19} is an alkylene group
25 having 2-4 carbon atoms and f is an integer of 5-70, and
a polyoxyalkylene glycol glycerol ether represented by the general formula (5)



wherein $\text{R}^{20}-\text{R}^{22}$ are each a hydrogen atom or an alkyl group having 1-18 carbon atoms, $\text{R}^{23}-\text{R}^{25}$ are each an alkylene group having 2-4 carbon atoms and g-i are each an integer of 5-7.

These conventional oils represented by the formulae (4) and (5) may be used singly or jointly for adding to the refrigerator oil of this invention. Further, the refrigerator oil of this invention may be incorporated with paraffinic mineral oils, naphthenic mineral oils, poly α -olefins, alkylbenzenes and the like, but, in this case, the resulting mixed oil will be lowered in compatibility with hydrogen-containing halogenocarbons.

The amount of these conventional base oils so incorporated is not particularly limited as far as the excellent performances of the refrigerator oil of this invention are not impaired, but the esters [I]-[IV] should be present in the resulting mixed oil in a ratio of usually more than 50 % by weight, preferably not less than 70 % by weight of the total amount of the mixed oil.

To further improve the refrigerator oil of the present invention in thermal stability and chemical stability, it is incorporated with at least an epoxy

compound. The epoxy compound used herein is preferably selected from the group consisting of phenylglycidyl ether epoxy compounds, alkylglycidyl ether epoxy compounds, glycidyl ester epoxy compounds, aryloxirane compounds, 5 alkyloxirane compounds, alicyclic epoxy compounds, epoxidized fatty acid monoesters and epoxidized vegetable oils.

The said phenylglycidyl ether epoxy compounds used herein include phenylglycidyl ether and derivatives thereof 10 such as alkylphenylglycidyl ethers. The said alkylphenylglycidyl ethers are those having 1 to 3 alkyl groups having 1 to 13 carbon atoms, among which are preferred those having an alkyl group having 4 to 10 carbon atoms, such as n-butylphenylglycidyl ether, i- 15 butylphenylglycidyl ether, sec-butylphenylglycidyl ether, tert-butylphenylglycidyl ether, pentylphenylglycidyl ether, hexylphenylglycidyl ether, heptylphenylglycidyl ether, octylphenylglycidyl ether, nonylphenylglycidyl ether and decylphenylglycidyl ether.

20 The alkylglycidyl ether epoxy compounds include decylglycidyl ether, undecylglycidyl ether, dodecylglycidyl ether, tridecylglycidyl ether, tetradecylglycidyl ether, 2-ethylhexylglycidyl ether, neopentyl glycol diglycidyl ether, trimethylolpropane triglycidyl ether, pentaerythritol 25 tetraglycidyl ether, 1,6-hexanediol diglycidyl ether, sorbitol polyglycidyl ether, polyalkylene glycol

monoglycidyl ethers and polyalkylene glycol diglycidyl ethers.

The glycidyl ester epoxy compounds include phenylglycidyl esters, alkylglycidyl esters and
5 alkenylglycidyl esters with glycidyl 2,2-dimethyl octanoate, glycidyl benzoate, glycidyl acrylate, glycidyl methacrylate and the like being preferred.

The aryloxirane compounds include 1,2-epoxystyrene and alkyl-1,2-epoxystyrene.

10 The alkyloxirane compounds include 1,2-epoxybutane, 1,2-epoxypentane, 1,2-epoxyhexane, 1,2-epoxyheptane, 1,2-epoxyoctane, 1,2-epoxynonane, 1,2-epoxydecane, 1,2-epoxyundecane, 1,2-epoxydodecane, 1,2-epoxytridecane, 1,2-epoxytetradecane, 1,2-epoxypentadecane, 1,2-epoxyhexadecane,
15 1,2-epoxyheptadecane, 1,1,2-epoxyoctadecane, 2-epoxynonadecane and 1,2-epoxyeicosane.

The alicyclic epoxy compounds include 1,2-epoxycyclohexane, 1,2-epoxycyclopentane, 3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate, bis
20 (3,4-epoxycyclohexylmethyl) adipate, exo-2,3-epoxynorbornane, bis (3,4-epoxy-6-methylcyclohexylmethyl) adipate, 2-(7-oxabicyclo[4.1.0]hept-3-yl)-spiro(1,3-dioxane-5,3'-[7]oxabicyclo[4.1.0]heptane, 4-(1'-methylepoxyethyl)-1,2-epoxy-2-methylcyclohexane and 4-epoxyethyl-1,2-
25 epoxycyclohexane.

The epoxidized fatty acid monoesters include esters of an epoxidized fatty acid having 12 to 20 carbon atoms and

an alcohol having 1 to 8 carbon atoms, phenol or an alkylphenol. In particular, butyl, hexyl, benzyl, cyclohexyl, methoxyethyl, octyl, phenyl or butylphenyl esters of epoxidized stearic acid may preferably be used.

- 5 The epoxidized vegetable oils include epoxidized compounds of vegetable oils such as soybean oil, linseed oil and cottonseed oil.

 Among these epoxy compounds, the preferable ones include phenylglycidyl ether epoxy compounds, alkylglycidyl
10 ether type epoxy compounds, glycidyl ester type epoxy compounds and alicyclic epoxy compounds.

 It is desirable that these epoxy compounds be incorporated in the refrigerator oil of the present invention in a ratio of 0.1-5.0% by weight, preferably 0.2-
15 2.0% by weight, of the total amount of the refrigerator oil.

 The refrigerator oil composition according to this invention may be incorporated further with at least one kind of a phosphorus compound selected from the group consisting of phosphoric esters, acid phosphoric esters, amine salts of
20 acid phosphoric esters, chlorinated phosphoric esters and phosphorous esters, to improve the oil composition in wear resistance and load resistance. These phosphorus compounds are esters of phosphoric acid or phosphorous acid and an alkanol or a polyether type alcohol, or derivatives of the
25 esters. The phosphoric esters are exemplified by tributyl phosphate, triphenyl phosphate and tricresyl phosphate. The acid phosphoric esters are exemplified by ditetradecyl acid

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phosphate, dipentadecyl acid phosphate, dihexadecyl acid
phosphate, diheptadecyl acid phosphate and dioctadecyl acid
phosphate. The amine salts of acid phosphoric esters are
exemplified by salts of the above acid phosphoric esters and
5 amines such as methylamine, ethylamine, propylamine,
butylamine, pentylamine, hexylamine, heptylamine,
octylamine, dimethylamine, diethylamine, dipropylamine,
dibutylamine, dipentylamine, dihexylamine, diheptylamine,
dioctylamine, trimethylamine, triethylamine, tripropylamine,
10 tributylamine, tripentylamine, trihexylamine, triheptylamine
and trioctylamine. The chlorinated phosphoric esters are
exemplified by tris-dichloropropyl phosphate,
tris-chloroethyl phosphate,
polyoxyalkylene-bis[di(chloroalkyl)] phosphate and
15 tris-chlorophenyl phosphate. The phosphorous esters are
exemplified by dibutyl phosphite, tributyl phosphite,
dipentyl phosphite, tripentyl phosphite, dihexyl phosphite,
trihexyl phosphite, diheptyl phosphite, triheptyl phosphite,
dioctyl phosphite, trioctyl phosphite, dinonyl phosphite,
20 didecyl phosphite, diundecyl phosphite, triundecyl
phosphite, didodecyl phosphite, tridodecyl phosphite,
diphenyl phosphite, triphenyl phosphite, dicresyl phosphite,
tricresyl phosphite and mixtures thereof. These phosphorus
compounds may be added to the refrigerator oil in a ratio of
25 0.1-5.0 % by weight, preferably 0.2-2.0 % by weight, of the
total amount of the refrigerator oil.

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Of course, both of the aforementioned phosphorus compounds and epoxy compounds may be used jointly.

To further enhance the refrigerator oil of this invention in performances, the refrigerator oil may be
5 incorporated, as required, with heretofore known additives for a refrigerator oil, which include phenol-type antioxidants such as di-tert.-butyl-p-cresol and bisphenol A; amine-type antioxidants such as phenyl- α -naphthylamine and N,N-di(2-naphthyl)-p-phenylenediamine; wear resistant
10 additives such as zinc dithiophosphate; extreme pressure agents such as chlorinated paraffin and sulfur compounds; oiliness improvers such as fatty acids; antifoaming agents such as silicone-type ones; and metal inactivators such as benzotriazole. These additives may be used singly or
15 jointly. The total amount of these additives added is ordinarily not more than 10 % by weight, preferably not more than 5 % by weight, of the total amount of the refrigerator oil.

The refrigerator oils of this invention comprising at
20 least one of the esters [I]-[IV] as the base oil should have such viscosity and pour point as those which are normally suitable for an ordinary refrigerator oil, but they should desirably have a pour point of not higher than -10°C , preferably -20°C to -80°C , to prevent them from
25 solidification at a low temperature. Further, they should desirably have a kinematic viscosity of not less than 2cSt, preferably not less than 3cSt at 100°C , to keep the

sealability of the compressor when used, while they should desirably have a kinematic viscosity of not more than 150cSt, preferably not more than 100cSt at 100°C, in view of their fluidity at a low temperature and the efficiency of
5 heat exchange in the evaporator when used.

The refrigerants which may be used in refrigerators in which the lubricating oils (refrigerator oils) of the present invention are suitably used, include hydrogen-containing halogenocarbons such as alkane fluorides having
10 1-3 carbon atoms, preferably 1-2 carbon atoms and/or alkane chloride fluoride having 1-3 carbon atoms, preferably 1-2 carbon atoms. The said hydrogen-containing halogenocarbons are exemplified by HFCs (chlorine-free type halogenocarbons) such as difluoromethane (HFC-32), trifluoromethane (HFC-23),
15 pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a) and 1,1-difluoroethane (HFC-152a); HCFCs (chlorine-containing type halogenocarbons) such as monochlorodifluoromethane (HCFC-22), 1-chloro-1,1-
20 difluoroethane (HCFC-142b), dichlorotrifluoroethane (HCFC-123) and monochlorotetrafluoroethane (HCFC-124); and mixtures thereof. Among these hydrogen-containing halogenocarbons, the chlorine-free type halogenocarbons such as HFC-32, HFC-23, HFC-125, HFC-134, HFC-134a and HFC-152a,
25 are preferable in view of the environmental problems. The refrigerant used may suitably be selected from these halogenocarbons mentioned above depending on the purpose for

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halogenocarbons as compared with the heretofore known refrigerator oils. Further, the refrigerator oils of the present invention are excellent because they have not only high compatibility with the hydrogen-containing

5 halogenocarbons and high electrical insulating property but also high lubricity, low hygroscopicity and high thermal and chemical stability.

The refrigerator oils of the present invention may particularly preferably be used in refrigerators, air-
10 conditioners, dehumidifiers, cold-storage chests, freezers, freeze and refrigeration warehouses, automatic vending machines, showcases, cooling units in chemical plants, and the like which have a reciprocating or rotary compressor. Further, the above refrigerator oils may also preferably be
15 used in refrigerators having a centrifugal compressor.

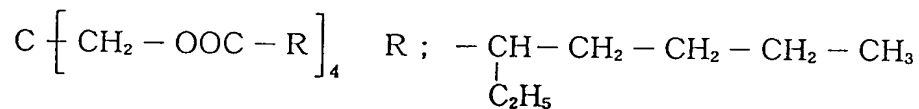
This invention will be better understood by the following Examples and Comparative Examples.

Examples 1-69 and Comparative Examples 1-70

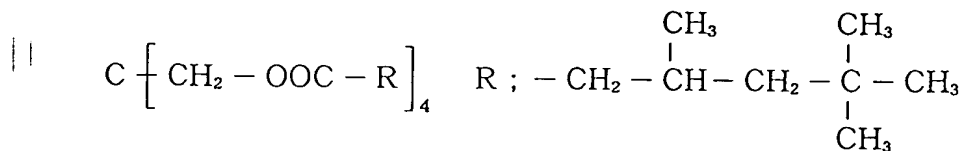
20 First, base oils according to this invention (Base oils 1-23 and 30) and comparative base oils of conventional types (Base oils 24-29 and 31-49), which are used in the Examples and Comparative Examples, respectively, are illustrated as follows:

25

[Base oil 1] A tetraester of pentaerythritol (1 mol) and 2-ethylhexanoic acid (4 mol):



5 [Base oil 2] A tetraester of pentaerythritol (1 mol) and 3,5,5-trimethylhexanoic acid (4 mol):

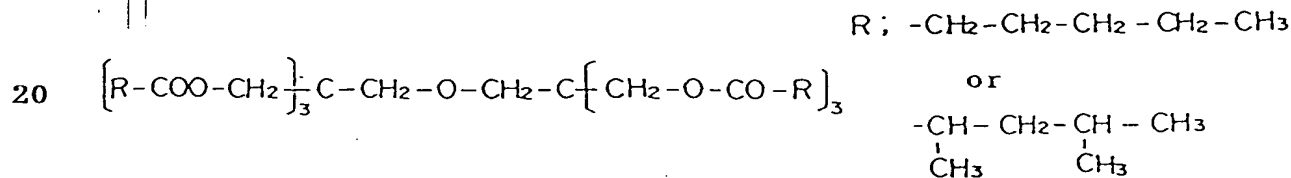


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[Base oil 3] A tetraester of pentaerythritol (1 mol), 2-ethylhexanoic acid (2 mol) and 3,5,5-trimethylhexanoic acid (2 mol)

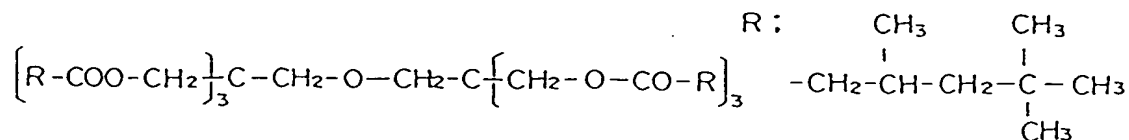
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[Base oil 4] A hexaester of dipentaerythritol (1 mol), n-hexanoic acid (3 mol) and 2,4-dimethylpentanoic acid (3 mol):



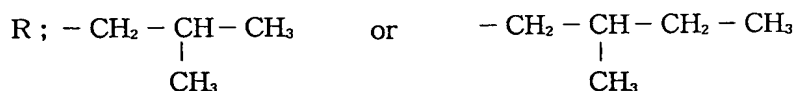
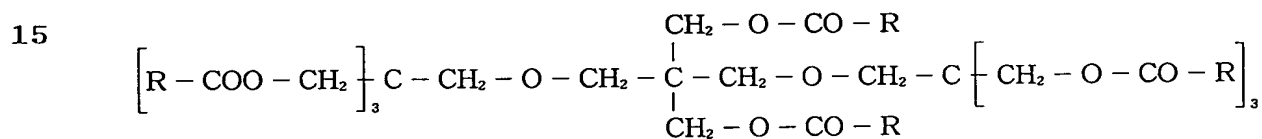
25 [Base oil 5] A hexaester of dipentaerythritol (1 mol) and 3,5,5-trimethylhexanoic acid (6 mol):

||



- 5 [Base oil 6] A mixture of 50 parts by weight of the same ester as in Base oil 1 and 50 parts by weight of the same ester as in Base oil 5

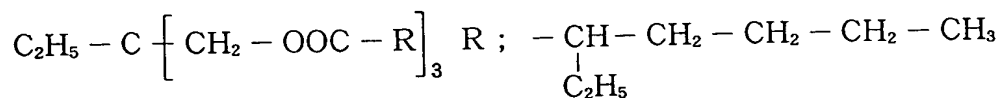
- 10 [Base oil 7] A mixture of 30 parts by weight of the same ester as in Base oil 2, 40 parts by weight of the same ester as in Base oil 5 and 30 parts by weight of the following octaester of tripentaerythritol (1 mol), 3-methylbutanoic acid (4 mol) and 3-methylpentanoic acid (4 mol):



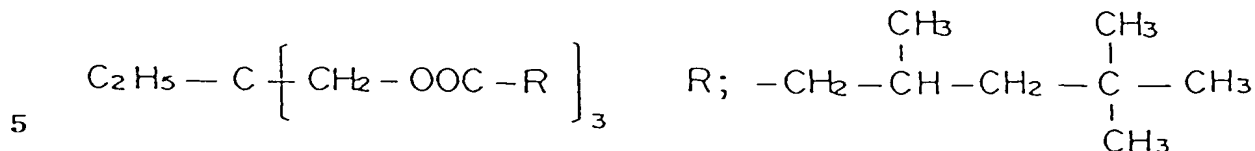
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- [Base oil 8] A triester of trimethylolpropane (1 mol) and 2-ethylhexanoic acid (3 mol):

||

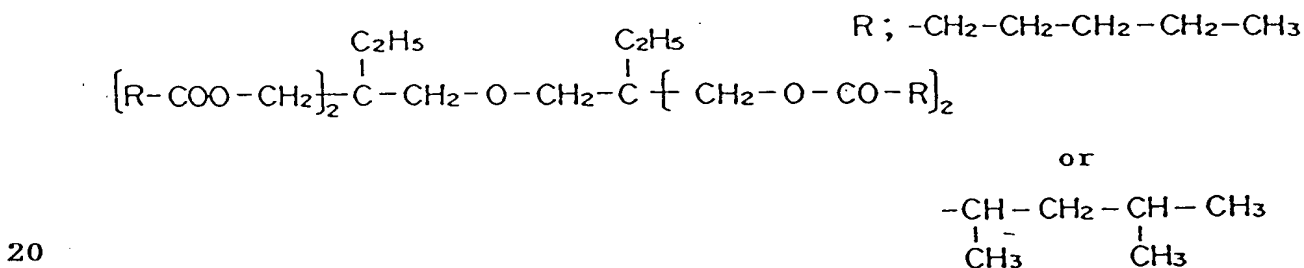


[Base oil 9] A triester of trimethylolpropane (1 mol) and 3,5,5-trimethylhexanoic acid (3 mol):

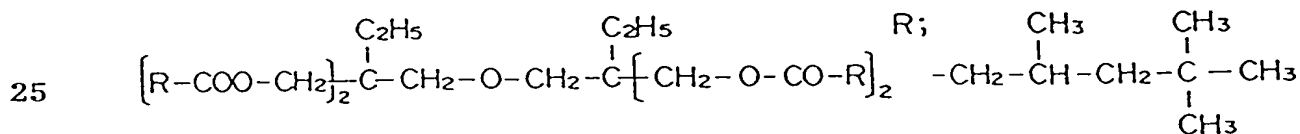


10 [Base oil 10] A triester of trimethylolpropane (1 mol), 2-ethylhexanoic acid (1.5 mol) and 3,5,5-trimethylhexanoic acid (1.5 mol)

15 [Base oil 11] A tetraester of di-(trimethylolpropane) (1 mol), n-hexanoic acid (2 mol) and 2,4-dimethylpentanoic acid (2 mol):



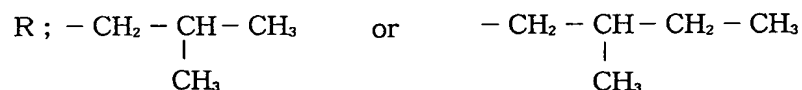
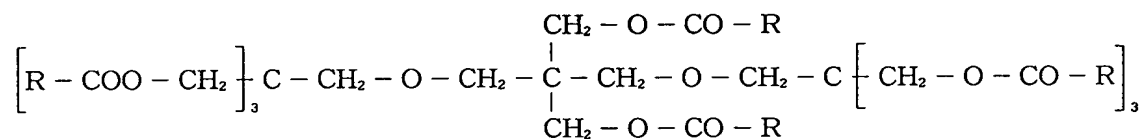
[Base oil 12] A tetraester of di-(trimethylolpropane) (1 mol) and 3,5,5-trimethylhexanoic acid (4 mol):



[Base oil 13] A mixture of 50 parts by weight of the same ester as in Base oil 8 and 50 parts by weight of the same ester as in Base oil 12

- 5 [Base oil 14] A mixture of 30 parts by weight of the same ester as in Base oil 9, 40 parts by weight of the same ester as in Base oil 12 and 30 parts by weight of the following octaester of tripentaerythritol (1 mol), 3-methylbutanoic acid (4 mol) and 3-methylpentanoic acid (4 mol):

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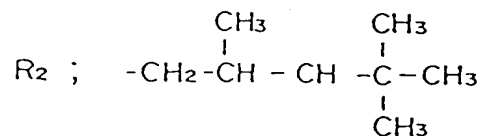
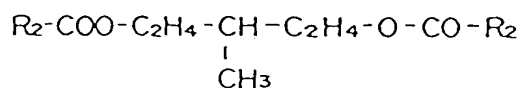
[Base oil 15] A diester of adipic acid and 2-ethyl-1-hexanol:

20



[Base oil 16] A diester of 3-methyl-1,5-pentanediol and 3,5,5-trimethylhexanoic acid:

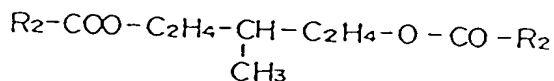
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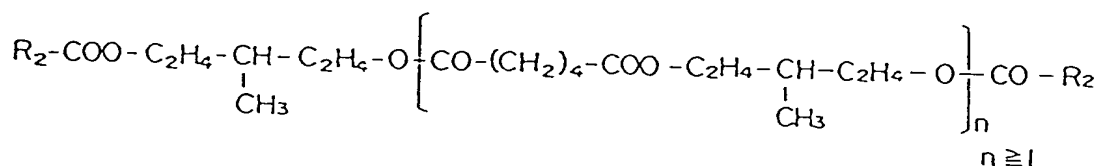
[Base oil 17] A complex ester having an average molecular weight of about 500 of 3-methyl-1,5-pentanediol, adipic acid and 3,5,5-trimethylhexanoic acid:

10



and

15



R^2 ; the same as in Base oil 16

20

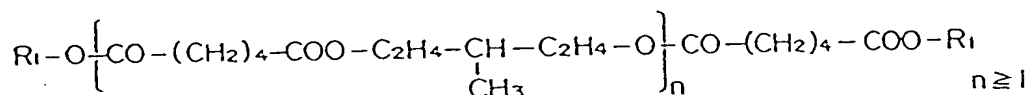
[Base oil 18] A complex ester having the same composition as that in Base oil 17 except for having an average molecular weight of about 700

25

[Base oil 19] A complex ester having an average molecular weight of about 520 of 3-methyl-1,5-pentanediol, adipic acid and 2-ethyl-1-hexanol:



and



5

[Base oil 20] A complex ester having the same composition as that in Base oil 19 except for having an average molecular weight of about 750

10

[Base oil 21] A mixture of the same complex ester as in Base oil 17 and 1.0 wt.% of a phosphoric ester type wear inhibitor

15

[Base oil 22] An ester having an average molecular weight of 690 and a kinematic viscosity at 100°C of 9.6 cSt, obtained by the reaction of 2 moles of trimethylolpropane with 1 mole of succinic acid, 1 mole of glutaric acid, 2 moles of iso-pentanoic acid and 2 moles of iso-hexanoic acid

20

[Base oil 23] An ester having an average molecular weight of 880 and a kinematic viscosity at 100 °C of 12.7 cSt, obtained by the reaction of 2 moles of pentaerythritol with 1 mole of succinic acid, 1 mole of glutaric acid, 3 moles of iso-pentanoic acid and 3 moles of iso-hexanoic acid

25

[Base oil 24] A naphthenic mineral oil

60160-6035T60

[Base oil 25] A branched-chain type alkylbenzene (average molecular weight: about 300)

[Base oil 26] Polyoxypropylene glycol monobutyl ether
5 (average molecular weight: about 500)

[Base oil 27] Polyoxypropylene glycol monobutyl ether
(average molecular weight: about 1000)

10 [Base oil 28] Polyoxypropylene glycol (average molecular weight: about 700)

[Base oil 29] Polyoxypropylene glycol (average molecular weight: about 2000)

15

[Base oil 30] A tetraester of pentaerythritol (1 mol) and n-nonanoic acid (4 mol)

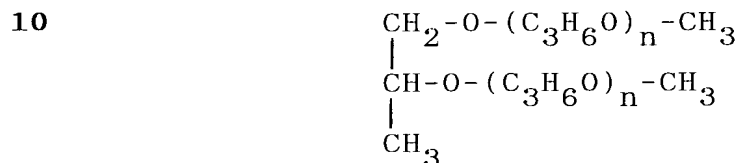
[Base oil 31] A tetraester of pentaerythritol (1 mol) and
20 coconut oil

[Base oil 32] A triester of trimethylolpropane (1 mol) and n-nonanoic acid (3 mol)

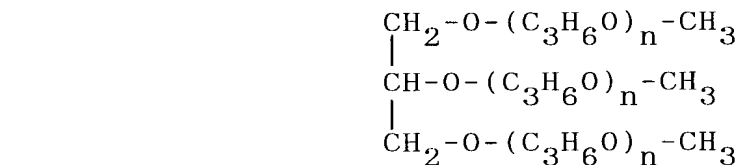
25 [Base oil 33] A triester of trimethylolpropane (1 mol) and coconut oil

[Base oil 34] Polyoxyethyleneoxypropylene glycol mono n-butyl ether (number-average molecular weight = 670, kinematic viscosity at 100 °C = 7.1 mm²/s, weight ratio of oxyethylene groups to oxypropylene groups in polyoxy-alkylene chain = 1 : 1)

[Base oil 35] Propylene glycol derivative of polyoxypropylene glycol mono methyl ether (number-average molecular weight = 1100, kinematic viscosity at 100 °C = 11.3 mm²/s):



[Base oil 36] Glycerol derivative of polyoxypropylene glycol mono methyl ether (number-average molecular weight = 1300, kinematic viscosity at 100 °C = 12.8 mm²/s):



[Base oil 37] Mixture of base oil 1 and base oil 27 (weight ratio of base oil 1 to base oil 27 = 70 : 30)

[Base oil 38] Mixture of base oil 1 and base oil 27 (weight ratio of base oil 1 to base oil 27 = 50 : 50)

[Base oil 40] Mixture of base oil 1 and base oil 36 (weight ratio of base oil 1 to base oil 36 = 70 : 30)

10 [Base oil 42] Mixture of base oil 3 and base oil 36 (weight ratio of base oil 3 to base oil 36 = 30 : 70)

15

[Base oil 44] Mixture of base oil 5 and base oil 27 (weight ratio of base oil 5 to base oil 27 = 50 : 50)

[Base oil 46] Mixture of base oil 7 and base oil 27 (weight ratio of base oil 7 to base oil 27 = 30 : 70)

25 [Base oil 47] Mixture of base oil 1 and base oil 27 (weight
ratio of base oil 1 to base oil 27 = 95 : 5)

[Base oil 48] Mixture of base oil 1 and base oil 34 (weight ratio of base oil 1 to base oil 34 = 95 : 5)

[Base oil 49] Mixture of base oil 30 and base oil 27
5 (weight ratio of base oil 30 to base oil 27 = 95 : 5)

The refrigerator oils of Examples 1-69 according to the present invention each of which has a composition indicated in the following Table 1 were prepared and then
10 evaluated for their ^{performance specifically} ~~performances that are~~ their miscibility with HFC-134a, insulating property, wear resistance, hygroscopicity and thermal and chemical stability by the following respective test methods. The results thus obtained are indicated in Table 1.

15 For comparison, the mineral oil (Comparative Example 1), the alkylbenzene (Comparative Example 2), the polypropylene glycol monoalkyl ethers and derivatives thereof (Comparative Examples 3, 4, 34-45, 62 and 63), the polypropylene glycols (Comparative Examples 5 and 6), the
20 straight-chain fatty acid esters of polyol alcohols (Comparative Examples 8-10) which are free from epoxy compounds and have heretofore been used as refrigerator oils, mixed oils of the polypropylene glycol monoalkyl ethers or derivatives thereof with the esters of the present
25 invention (Comparative Examples 46-61 and 64-70), mixed oils of the tetraester of pentaerythritol, as well as Base oils 1-23 (Comparative Examples 11-33) which are free from epoxy

compounds, were evaluated for their performances in the same manner as in Examples 1-72. The results thus obtained are indicated in Table 2.

5 (Miscibility with HFC-134a)

0.2 g of the test oil of each of the Examples (Examples 1-23 and 67-69) and the Comparative Examples (Comparative Examples 1-33 and 70) and 1.8 g of the refrigerant (HFC-134a) as well as 0.06 g of the test oil of each of the Examples (Examples 1-23 and 67-69) and the Comparative Examples (Comparative Examples 11-33 and 70) and 1.94 g of the refrigerant (HFC-134a) were sealed in a glass tube having an inner diameter of 6 mm and a length of 220 mm. This glass tube was then placed in a thermostat maintained at a predetermined low temperature or high temperature to observe whether the refrigerant and the test oil were miscible with each other, separated from each other or made white-turbid.

20 (Insulating property)

The test oils were each measured for specific volume resistivity at 25°C in accordance with JIS C 2101.

(FALEX wear test)

25 The test oils were each applied to a test journal for measuring the amount of the test journal worn by having the journal run in at a test oil temperature of 100 °C under a

load of 150 lb for 1 minute and then running it under a load of 250 lb for 2 hours in accordance with ASTM D 2670.

(Hygroscopicity)

- 5 Thirty grams (30 g) of each of the test oils were placed in a 300-ml beaker, allowed to stand for 7 days in an air-conditioned bath maintained at a temperature of 30 °C and a humidity of 60 % and then measured for water content by the Karl-Fischer method.

10

(Thermal and chemical stability)

Thermal and chemical stabilities of the test oils were evaluated by the following sealed tube test with HFC-134a in accordance with JIS K 2211 4.9.

15

An equi-volume mixture of each of the test oils and the refrigerant (HFC-134a) was sealed, together with copper, iron and aluminum catalysts, in a glass tube and then heated to 250°C for 168 hours to observe discoloration of the test oil and surface states of the catalysts and determine the

20

degree of discoloration. The degree of discoloration of the test oil was classified into 9 grades ranging from 0 (no discoloration) to 8 (black-brown color).

Fifty grams (50 g) of each of the test oils (Examples 24-66 and Comparative Examples 34-69) indicated in the

25

Tables were placed in a 100-ml beaker, and then allowed to stand for 168 hours in an air-conditioned bath maintained at a temperature of 25 °C and a relative humidity of 80%.

25

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

Examples	Comparative Examples	Base oils	Epoxy compounds*		TCP*** Amount (In wt%)	DBPC***** Amount (In wt%)	Kinematic viscosity @100°C (mm ² /s)	Miscible Temp. Range with HFC-134a (°C)		Resistivity @25°C (Ωcm)	Falex test Amount of Journal worn (mg)	Hygroscopicity 30°C, 60% (1)	Sealed tube test				
			Kind	Amount (In wt%)				Amount of HFC-134a (90 wt%)	Amount of HFC-134a (97 wt%)				Oil color	Catalyst			Appearance of test oil
														Cu	Fe	Al	
Example 1	1	PGE	0.5	none	none	6.2	-27~CT**	-45~CT**	4.2×10 ⁻⁴	26	0.19	1	No change	No change	No change	----	
Example 2	2	s-BuPGE	0.5	none	none	11.5	-32~CT**	-60~CT**	3.8×10 ⁻⁴	25	0.20	1	No change	No change	No change	----	
Example 3	3	t-BuPGE	0.5	none	none	8.1	-28~CT**	-45~CT**	3.9×10 ⁻⁴	26	0.18	1	No change	No change	No change	----	
Example 4	4	DODECYLGE	0.5	none	none	10.0	<70~CT**	<70~CT**	2.9×10 ⁻⁴	21	0.18	1	No change	No change	No change	----	
Example 5	5	DECYLGEs	0.5	none	none	28.2	-7~75	-18~90	3.0×10 ⁻⁴	19	0.16	1	No change	No change	No change	----	
Example 6	6	EPCH	0.5	none	none	11.8	-25~90	-36~CT**	3.1×10 ⁻⁴	21	0.16	1	No change	No change	No change	----	
Example 7	7	EP. DODEC.	0.5	none	none	32.3	-5~86	<70~CT**	2.4×10 ⁻⁴	19	0.12	1	No change	No change	No change	----	
Example 8	8	PGE	1.0	none	none	3.7	-35~CT**	<70~CT**	4.5×10 ⁻⁴	27	0.21	1	No change	No change	No change	----	
Example 9	9	s-BuPGE	1.0	none	none	9.4	-45~CT**	<70~CT**	4.0×10 ⁻⁴	27	0.20	1	No change	No change	No change	----	
Example 10	10	t-BuPGE	1.0	none	none	7.1	-37~CT**	<70~CT**	4.1×10 ⁻⁴	25	0.22	1	No change	No change	No change	----	
Example 11	11	DODECYLGE	1.0	none	none	9.0	<70~CT**	-25~CT**	2.7×10 ⁻⁴	23	0.17	1	No change	No change	No change	----	
Example 12	12	DECYLGEs	1.0	none	none	22.0	-11~75	-38~17	2.8×10 ⁻⁴	20	0.14	1	No change	No change	No change	----	
Example 13	13	EPCH	1.0	none	none	9.7	-20~0	-21~CT**	3.1×10 ⁻⁴	25	0.15	1	No change	No change	No change	----	
Example 14	14	EP. DODEC.	1.0	none	none	31.8	-7~88	-19~CT**	2.7×10 ⁻⁴	20	0.12	1	No change	No change	No change	----	
Example 15	15	EP. SOY.	1.0	none	none	2.3	-24~CT**	-38~CT**	4.0×10 ⁻⁴	23	0.22	1	No change	No change	No change	----	
Example 16	16	EP. St. B	1.0	none	none	3.0	-30~CT**	-54~CT**	3.9×10 ⁻⁴	20	0.21	1	No change	No change	No change	----	
Example 17	17	PGE	2.0	none	none	5.3	-55~CT**	<70~CT**	2.4×10 ⁻⁴	16	0.16	1	No change	No change	No change	----	
Example 18	18	s-BuPGE	2.0	none	none	10.1	-34~95	-60~CT**	1.4×10 ⁻⁴	11	0.11	1	No change	No change	No change	----	
Example 19	19	t-BuPGE	2.0	none	none	6.0	-47~CT**	<70~CT**	2.4×10 ⁻⁴	11	0.17	1	No change	No change	No change	----	
Example 20	20	DODECYLGE	2.0	none	none	11.4	-32~92	-56~CT**	1.1×10 ⁻⁴	10	0.11	1	No change	No change	No change	----	
Example 21	21	DECYLGEs	2.0	none	none	5.3	-55~CT**	<70~CT**	2.5×10 ⁻⁴	3	0.16	0	No change	No change	No change	----	
Example 22	22	EPCH	2.0	none	none	9.4	<35~76	<50~CT**	2.9×10 ⁻⁴	19	0.20	1	No change	No change	No change	----	
Example 23	23	EP. DODEC.	2.0	none	none	12.5	<30~88	<50~CT**	1.4×10 ⁻⁴	16	0.12	1	No change	No change	No change	----	
Example 24	1	PGE	3.0	none	none	6.0	----	----	4.2×10 ⁻⁴	----	0.19	----	----	----	----	No change	
Example 25	2	s-BuPGE	3.0	none	none	11.3	----	----	3.8×10 ⁻⁴	----	0.20	----	----	----	----	No change	
Example 26	3	t-BuPGE	3.0	none	none	7.9	----	----	3.9×10 ⁻⁴	----	0.18	----	----	----	----	No change	

Table 1 (Cont.)

Example 27	4	DODECYLGE	3.0	none	none	10.0	---	---	2.9×10^{14}	---	0.18	---	---	---	No change
Example 28	5	DECYLGEs	3.0	none	none	28.0	---	---	3.0×10^{14}	---	0.16	---	---	---	No change
Example 29	6	EPCH	3.0	none	none	11.6	---	---	3.1×10^{14}	---	0.16	---	---	---	No change
Example 30	7	EP. DODEC.	3.0	none	none	32.1	---	---	2.4×10^{14}	---	0.12	---	---	---	No change
Example 31	8	PGE	3.0	none	none	3.5	---	---	4.5×10^{14}	---	0.21	---	---	---	No change
Example 32	9	s-BuPGE	3.0	none	none	9.2	---	---	4.0×10^{14}	---	0.20	---	---	---	No change
Example 33	10	t-BuPGE	3.0	none	none	6.9	---	---	4.1×10^{14}	---	0.22	---	---	---	No change
Example 34	11	DODECYLGE	3.0	none	none	8.8	---	---	2.7×10^{14}	---	0.17	---	---	---	No change
Example 35	12	DECYLGEs	3.0	none	none	21.8	---	---	2.8×10^{14}	---	0.14	---	---	---	No change
Example 36	13	EPCH	3.0	none	none	9.5	---	---	3.1×10^{14}	---	0.15	---	---	---	No change
Example 37	14	EP. DODEC.	3.0	none	none	31.6	---	---	2.7×10^{14}	---	0.12	---	---	---	No change
Example 38	15	EP. SOY.	3.0	none	none	2.1	---	---	4.0×10^{14}	---	0.22	---	---	---	No change
Example 39	16	EP. St. B	3.0	none	none	2.9	---	---	3.9×10^{14}	---	0.21	---	---	---	No change
Example 40	17	PGE	3.0	none	none	5.3	---	---	2.4×10^{14}	---	0.16	---	---	---	No change
Example 41	18	s-BuPGE	3.0	none	none	10.1	---	---	1.4×10^{14}	---	0.11	---	---	---	No change
Example 42	19	t-BuPGE	3.0	none	none	6.0	---	---	2.4×10^{14}	---	0.17	---	---	---	No change
Example 43	20	DODECYLGE	3.0	none	none	11.4	---	---	1.1×10^{14}	---	0.11	---	---	---	No change
Example 44	21	DECYLGEs	3.0	none	none	5.3	---	---	2.5×10^{14}	---	0.16	---	---	---	No change
Example 45	22	EPCH	3.0	none	none	9.4	---	---	2.9×10^{14}	---	0.20	---	---	---	No change
Example 46	23	EP. DODEC.	3.0	none	none	12.5	---	---	1.4×10^{14}	---	0.12	---	---	---	No change
Example 47	2	PGE	3.0	none	none	11.2	---	---	3.8×10^{14}	---	0.20	---	---	---	No change
Example 48	3	PGE	3.0	none	none	7.9	---	---	3.9×10^{14}	---	0.18	---	---	---	No change
Example 49	4	PGE	3.0	none	none	9.8	---	---	2.9×10^{14}	---	0.18	---	---	---	No change
Example 50	5	PGE	3.0	none	none	28.0	---	---	3.0×10^{14}	---	0.16	---	---	---	No change
Example 51	6	PGE	3.0	none	none	11.6	---	---	3.1×10^{14}	---	0.16	---	---	---	No change
Example 52	7	PGE	3.0	none	none	32.0	---	---	2.4×10^{14}	---	0.12	---	---	---	No change
Example 53	1	s-BuPGE	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 54	1	t-BuPGE	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 55	1	DODECYLGE	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 56	1	DECYLGEs	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 57	1	EPCH	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 58	1	EP. DODEC.	3.0	none	none	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 59	1	PGE	1.0	none	none	6.2	---	---	4.2×10^{14}	---	0.19	---	---	---	No change

Table 1 (Cont.)

Example 60	1	PGE	3.0	none	0.2	6.0	---	---	4.2×10^{14}	---	0.19	---	---	---	No change
Example 61	2	s-BuPGE	3.0	none	0.2	11.3	---	---	3.8×10^{14}	---	0.20	---	---	---	No change
Example 62	3	t-BuPGE	3.0	none	0.2	7.9	---	---	3.9×10^{14}	---	0.18	---	---	---	No change
Example 63	4	DODECYLGE	3.0	none	0.2	10.0	---	---	2.9×10^{14}	---	0.18	---	---	---	No change
Example 64	5	DECYLGEs	3.0	none	0.2	28.0	---	---	3.0×10^{14}	---	0.16	---	---	---	No change
Example 65	6	EPCH	3.0	none	0.2	11.6	---	---	3.1×10^{14}	---	0.16	---	---	---	No change
Example 66	7	EP, DODEC.	3.0	none	0.2	32.0	---	---	2.4×10^{14}	---	0.12	---	---	---	No change
Example 67	30	PGE	3.0	none	none	5.7	Immiscible	-24~CT**	2.1×10^{14}	16	0.21	No change	No change	No change	---
Example 68	30	s-BuPGE	3.0	none	none	5.7	Immiscible	-25~CT**	2.4×10^{14}	18	0.20	No change	No change	No change	---
Example 69	30	t-BuPGE	3.0	none	0.2	5.8	Immiscible	-25~CT**	2.3×10^{14}	19	0.21	No change	No change	No change	---

Table 2

Examples	Base oils	Epoxy compounds*		TCP*** Amount (In wt%)	DBPC***** Amount (In wt%)	Kinematic viscosity @100°C (mm ² /s)	Miscible Temp. Range with HFC-134a (°C)		Resistiv- ity @25°C (Ωcm)	Falex test Amount of journal worn (mg)	Hygro- scopicity 30°C, 60% (%)	Sealed tube test			
							Oil color	Catalyst				Appearance of test oil			
		Kind	Amount (In wt%)	Amount of HFC-134a (90 wt%)	Amount of HFC-134a (97 wt%)	Cu		Fe	Al						
Comp. Ex. 1	24	none	---	none	none	5.1	Immiscible	----	3.8×10 ¹⁵	23	0.01	----	----	----	----
Comp. Ex. 2	25	none	---	none	none	4.8	Immiscible	----	6.4×10 ¹⁵	25	0.01	----	----	----	----
Comp. Ex. 3	26	none	---	none	none	4.9	<70~97	----	1.1×10 ¹¹	40	1.31	----	----	----	----
Comp. Ex. 4	27	none	---	none	none	10.8	<70~56	----	1.2×10 ¹¹	35	1.01	----	----	----	----
Comp. Ex. 5	28	none	---	none	none	10.6	<70~64	----	5.6×10 ¹⁰	38	2.30	----	----	----	----
Comp. Ex. 6	29	none	---	none	none	22.4	-51~32	----	4.8×10 ¹⁰	30	1.81	----	----	----	----
Comp. Ex. 7	30	none	---	none	none	6.1	Immiscible	----	2.1×10 ¹⁴	25	0.21	1	No change	Luster decreased	No change
Comp. Ex. 8	31	none	---	none	none	4.9	Immiscible	----	-----	----	----	----	----	----	----
Comp. Ex. 9	32	none	---	none	none	5.4	Immiscible	----	-----	----	----	----	----	----	----
Comp. Ex. 10	33	none	---	none	none	4.4	Immiscible	----	-----	----	----	----	----	----	----
Comp. Ex. 11	1	none	---	none	none	6.2	-27~CT***	-45~CT***	4.1×10 ¹⁴	27	0.19	4	No change	Luster decreased	No change
Comp. Ex. 12	2	none	---	none	none	11.5	-32~CT***	-60~CT***	3.8×10 ¹⁴	25	0.19	4	No change	Luster decreased	No change
Comp. Ex. 13	3	none	---	none	none	8.1	-28~CT***	-45~CT***	4.0×10 ¹⁴	26	0.19	5	No change	Luster decreased	No change
Comp. Ex. 14	4	none	---	none	none	10.0	<70~CT***	<70~CT***	2.8×10 ¹⁴	22	0.17	5	No change	Luster decreased	No change
Comp. Ex. 15	5	none	---	none	none	28.2	-7~75	-18~90	3.0×10 ¹⁴	19	0.15	3	No change	Luster decreased	No change
Comp. Ex. 16	6	none	---	none	none	11.8	-25~90	-36~CT**	3.2×10 ¹⁴	22	0.16	3	No change	Luster decreased	No change
Comp. Ex. 17	7	none	---	none	none	32.3	-5~86	<70~CT**	2.4×10 ¹⁴	18	0.13	4	No change	Luster decreased	No change
Comp. Ex. 18	8	none	---	none	none	3.8	-35~CT***	<70~CT**	4.5×10 ¹⁴	29	0.20	4	No change	Luster decreased	No change
Comp. Ex. 19	9	none	---	none	none	9.5	-45~CT***	<70~CT**	3.9×10 ¹⁴	26	0.20	4	No change	Luster decreased	No change
Comp. Ex. 20	10	none	---	none	none	7.2	-37~CT***	<70~CT**	4.1×10 ¹⁴	26	0.20	6	No change	Luster decreased	No change
Comp. Ex. 21	11	none	---	none	none	9.1	<70~CT***	-25~CT**	2.5×10 ¹⁴	24	0.18	4	No change	Luster decreased	No change
Comp. Ex. 22	12	none	---	none	none	22.1	-11~75	-38~17	2.8×10 ¹⁴	20	0.14	4	No change	Luster decreased	No change
Comp. Ex. 23	13	none	---	none	none	9.8	-20~0	-21~CT**	3.0×10 ¹⁴	24	0.16	5	No change	Luster decreased	No change
Comp. Ex. 24	14	none	---	none	none	31.9	-7~88	-19~CT**	2.5×10 ¹⁴	19	0.14	3	No change	Luster decreased	No change
Comp. Ex. 25	15	none	---	none	none	2.3	-24~CT***	-38~CT**	4.2×10 ¹⁴	24	0.22	5	No change	Luster decreased	No change
Comp. Ex. 26	16	none	---	none	none	3.1	-30~CT***	-54~CT**	3.9×10 ¹⁴	22	0.20	4	No change	Luster decreased	No change

Table 2 (Cont.)

Comp. Ex. 27	17	none	---	none	none	5.5	-55~CT**	<70~CT**	2.5×10^{14}	15	0.18	4	No change	Luster decreased	No change	----
Comp. Ex. 28	18	none	---	none	none	10.3	-34~95	-60~CT**	1.4×10^{14}	12	0.11	4	No change	Luster decreased	No change	----
Comp. Ex. 29	19	none	---	none	none	6.2	-47~CT**	<70~CT**	2.2×10^{14}	14	0.16	5	No change	Luster decreased	No change	----
Comp. Ex. 30	20	none	---	none	none	11.6	-32~92	-56~CT**	1.1×10^{14}	10	0.10	4	No change	Luster decreased	No change	----
Comp. Ex. 31	21	none	---	none	none	5.5	-55~CT**	<70~CT**	2.3×10^{14}	2	0.18	2	No change	Luster decreased	No change	----
Comp. Ex. 32	22	none	---	none	none	9.6	<-35~76	<50~CT**	2.8×10^{14}	20	0.18	4	No change	Luster decreased	No change	----
Comp. Ex. 33	23	none	---	none	none	12.7	<-30~68	<50~CT**	1.2×10^{14}	17	0.12	3	No change	Luster decreased	No change	----
Comp. Ex. 34	27	PGE	3.0	none	none	10.6	---	---	1.2×10^{11}	---	1.01	---	---	---	---	White-turbid
Comp. Ex. 35	34	PGE	3.0	none	none	7.0	---	---	6.8×10^{10}	---	1.93	---	---	---	---	White-turbid
Comp. Ex. 36	34	s-BuPGE	3.0	none	none	7.0	---	---	6.8×10^{10}	---	1.93	---	---	---	---	White-turbid
Comp. Ex. 37	27	t-BuPGE	3.0	none	none	10.7	---	---	1.2×10^{11}	---	1.01	---	---	---	---	White-turbid
Comp. Ex. 38	34	DoDECYLGE	3.0	none	none	6.9	---	---	6.8×10^{10}	---	1.93	---	---	---	---	White-turbid
Comp. Ex. 39	27	DECYLGEs	3.0	none	none	10.6	---	---	1.2×10^{11}	---	1.01	---	---	---	---	White-turbid
Comp. Ex. 40	34	EPCH	3.0	none	none	6.9	---	---	6.8×10^{10}	---	1.93	---	---	---	---	White-turbid
Comp. Ex. 41	27	EP, DODEC.	3.0	none	none	10.7	---	---	1.2×10^{11}	---	1.01	---	---	---	---	White-turbid
Comp. Ex. 42	34	EP, SOY.	3.0	none	none	7.0	---	---	6.8×10^{10}	---	1.93	---	---	---	---	White-turbid
Comp. Ex. 43	27	EP, St. B	3.0	none	none	10.7	---	---	1.2×10^{11}	---	1.01	---	---	---	---	White-turbid
Comp. Ex. 44	35	PGE	3.0	none	none	11.2	---	---	1.0×10^{11}	---	1.10	---	---	---	---	White-turbid
Comp. Ex. 45	36	PGE	3.0	none	none	12.6	---	---	1.1×10^{11}	---	1.07	---	---	---	---	White-turbid
Comp. Ex. 46	37	PGE	3.0	none	none	7.2	---	---	6.8×10^{11}	---	0.47	---	---	---	---	White-turbid
Comp. Ex. 47	38	PGE	3.0	none	none	8.0	---	---	4.8×10^{11}	---	0.63	---	---	---	---	White-turbid
Comp. Ex. 48	39	PGE	3.0	none	none	6.3	---	---	8.4×10^{10}	---	1.78	---	---	---	---	White-turbid
Comp. Ex. 49	40	PGE	3.0	none	none	7.6	---	---	6.6×10^{11}	---	0.51	---	---	---	---	White-turbid
Comp. Ex. 50	41	PGE	3.0	none	none	11.5	---	---	3.8×10^{11}	---	0.74	---	---	---	---	White-turbid
Comp. Ex. 51	42	PGE	3.0	none	none	11.0	---	---	2.6×10^{11}	---	0.89	---	---	---	---	White-turbid
Comp. Ex. 52	43	PGE	3.0	none	none	10.4	---	---	3.8×10^{11}	---	0.60	---	---	---	---	White-turbid
Comp. Ex. 53	44	PGE	3.0	none	none	16.8	---	---	4.1×10^{11}	---	0.59	---	---	---	---	White-turbid
Comp. Ex. 54	45	PGE	3.0	none	none	11.4	---	---	8.7×10^{11}	---	0.42	---	---	---	---	White-turbid
Comp. Ex. 55	46	PGE	3.0	none	none	14.4	---	---	2.1×10^{11}	---	0.74	---	---	---	---	White-turbid
Comp. Ex. 56	39	S-BuPGE	3.0	none	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	---	White-turbid
Comp. Ex. 57	39	t-BuPGE	3.0	none	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	---	White-turbid
Comp. Ex. 58	39	DODECYLGE	3.0	none	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	---	White-turbid
Comp. Ex. 59	39	DECYLGEs	3.0	none	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	---	White-turbid

Table 2 (Cont.)

Comp. Ex. 60	39	EPCH	3.0	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	White-turbid
Comp. Ex. 61	39	EP, DODEC.	3.0	none	6.3	---	---	2.5×10^{11}	---	1.40	---	---	---	White-turbid
Comp. Ex. 62	27	PGE	3.0	1.0	10.5	---	---	1.2×10^{11}	---	1.01	---	---	---	White-turbid
Comp. Ex. 63	34	PGE	3.0	1.0	6.9	---	---	6.8×10^{10}	---	1.93	---	---	---	White-turbid
Comp. Ex. 64	37	PGE	3.0	1.0	7.1	---	---	6.8×10^{11}	---	0.47	---	---	---	White-turbid
Comp. Ex. 65	39	PGE	3.0	1.0	6.2	---	---	8.4×10^{10}	---	1.78	---	---	---	White-turbid
Comp. Ex. 66	47	PGE	3.0	1.0	6.1	---	---	2.1×10^{13}	---	0.22	---	---	---	White-turbid
Comp. Ex. 67	48	PGE	3.0	1.0	6.0	---	---	8.6×10^{12}	---	0.28	---	---	---	White-turbid
Comp. Ex. 68	47	PGE	3.0	none	6.2	---	---	2.1×10^{13}	---	0.22	---	---	---	White-turbid
Comp. Ex. 69	48	PGE	3.0	none	6.1	---	---	8.6×10^{12}	---	0.28	---	---	---	White-turbid
Comp. Ex. 70	49	PGE	3.0	none	6.0	Immiscible	-10~54	6.2×10^{12}	25	0.30	---	---	---	White-turbid

* PGE : Phenyl Glycidyl Ether

s-BuPGE : s-Butylphenyl Glycidyl Ether

t-BuPGE : t-Butylphenyl Glycidyl Ether

DODECYLGE : Dodecyl Glycidyl Ether

DECYLGE : Glycidyl 1,1-Dimethyloctanoate

EPCH : 1,2-Epoxylohexane

EP, DODEC. : 1,2-Epoxydodecane

EP, SOY. : Epoxydized Soy Bean Oil

EP, St. B : Epoxydized Butyl Stearate

** CT: Critical temperature of HFC-134a (102°C)

*** TCP: Tricresyl phosphate

**** DBPC: di-tert-butyl-P-cresol

It is apparent from the results indicated in the
Tables 1 and 2 that the refrigerator oils (Examples 1-23 and
67-69) of the present invention ^{are} at least miscible with 97%
by weight of a refrigerant, HFC-134a, and that the

5 refrigerator oils (Examples 1-23) of the present invention
are excellent in miscibility with the refrigerant as
compared with those of Comparative Examples 1-2.

Table 2 further shows that the ethers of Comparative
Examples 3 and 4 as well as the polyoxypropylene glycols of
10 Comparative Examples 5 and 6 are excellent in miscibility
with the refrigerant, but these ethers and glycols are
inferior in insulating property thereby rendering them
unusable for hermetic type compressors. Still further,
Table 2 shows that the ethers and glycols of Comparative
15 Examples 3-6 have hygroscopicity 5-10 times that of the
refrigerator oils of Examples 1-69 and are also inferior in
electrical insulating property, ice choke, wear resistance,
stability and the like to the refrigerator oils of the
Examples.

20 The FALEX wear test shows that the refrigerator oils
of Examples 1-23 and 67-69 are at least equal in wear
resistance to those of Comparative Examples 3-6.

The refrigerator oils of Comparative Examples 7 and
11-33 which are free from epoxy compounds are equivalent to
25 those of Examples 1-23 and 67-69 of the present invention in
miscibility with HFC-134a, insulating property, wear
resistance and hygroscopicity, but, as is apparent from the

5 The refrigerator oils of Comparative Examples 34-70 each of which contains at least a polypropylene glycol monoalkyl ether or a derivative thereof and an epoxy compound have a disadvantage that a precipitate which is insoluble into the base oil and the refrigerant is formed in the refrigerator oils due to deterioration of the epoxy compound during the storage under a high humidity. The formed precipitate makes the refrigerator oil white-turbid and leads to ^{the} danger of blocking an expansion valve and/or a capillary tube in a refrigerator system in which the above refrigerator oils of Comparative Examples 34-70 is used. Further, the refrigerator oils of Comparative Examples 34-70 have lower resistivity and higher hygroscopicity than any one of refrigerator oils of the present invention.

On the other hand, the refrigerator oils (Examples
20 24-69) of the present invention are free from the generation
of such a precipitate even if they are stored under a high
humidity. Therefore, in a case where the refrigerator oil
of the present invention is used in a refrigerator system,
there is no danger as mentioned above.

(Effect of the Invention)

As is apparent from the above comparative experiments, the refrigerator oils of the present invention are suitable for use in refrigerators using therein a hydrogen-containing halogenocarbon as a refrigerant and are excellent in electrical insulating property, wear resistance, nonhygroscopicity and thermal and chemical stability. In other words, the refrigerator oils of the present invention excellently have all properties which are important for refrigerator oils.

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